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XXVI. *Of the Degrees and Quantities of Winds requisite to move the heavier Kinds of Wind Machines. In a Letter from John Stedman, M. D. Fellow of the Royal College of Physicians at Edinburgh, to the Reverend Samuel Horsley, LL.D. Secretary to the Royal Society.*

S I R,

Edinburgh,
March 27, 1777.

Read Apr. 24,
1776.

THE irregularity and uncertainty of winds in this country have been found a considerable discouragement to erect wind machines. It hath frequently happened, that the proprietors of coal and other works, after having reared these kinds of engines, and having found them insufficient for the intended work, have been obliged to open mines, or to erect fire machines. This is chiefly owing to the undertakers reckoning upon more winds of a sufficient power to move these machines, than we commonly have in this country.

These machines are rarely erected with us, unless where a considerable moving power is necessary. This is always the case where the larger kind of pump-work is to be kept in motion, or where water is to be extracted from

from deep pits. Having enquired of many people concerned in such works, what may be the proportion of time in which wind machines may be kept in motion, to that in which they cannot move from a defect of wind, I found these people differing widely in their conjectures.

Having, however, met with one gentleman of observation and accuracy, who had erected a wind machine for draining his coal; he told me that, by the best computation he had been able to make, he never could depend upon more than fifty-three or fifty-four hours of wind sufficient for moving that machine, in a week, taking the year round. This is below what is commonly believed to be the proportion; but, so far as this can be rated by an estimate in the following manner, it will be found to be much about what may be depended upon for the heaviest kinds of machines; still making allowance for the differences of exposures, and for the strength and frequency of winds in one part of the country more than in another. We may here take notice of a circumstance favourable to the draining of coal-pits; that is, that the periods of the year in which the greatest quantities of rain fall, are likewise observed to abound with winds of the higher degrees. This seldom fails to hold in hilly countries, and particularly in those of high latitudes; that is, where the differences of heats in summer

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and of colds in winter are very considerable. The periods of the year here meant will generally be found to fall near the Equinoxes.

The only method of bringing the matter to a proper estimate is, by comparing the quantities of winds sufficient for moving these machines, with those of winds below that degree, and calms. This computation can only be drawn from journals in which the degrees of winds are noted. In the meteorological register of the Medical Effays of the Edinburgh Society, there is a column of winds, and four degrees are noted. This division is sufficient for the purposes for which that register was intended; but, when we consider the wind as a power acting upon machines, that number of degrees will be found too small.

Thus, from the second in that register to a hurricane, there is but one intermediate degree. As the second degree, which is very moderate, is insufficient for moving these machines; the third is more than just enough for that purpose. A degree, therefore, which is a mean betwixt these two, will be found to be the lowest that is sufficient for moving machines of the heavier kinds, particularly such as are used for pumping water out of coal-pits.

These

These three degrees of wind, that is the second and third of the Edinburgh register, and an intermediate degree, are very distinguishable even by the senses, and without the assistance of any instrument, by those who are attentive and have been accustomed to make observations of this nature.

To ascertain proportions of this nature, a longer term of years would have been more satisfactory; but, in case others should afterwards pursue this kind of computation, the proportions are digested in two tables at the end of this essay, and may be consulted occasionally.

In making up these tables, *viz.* one of the second degree and above, and the other of the third and upwards, hurricanes are included, though that degree of wind be too high for any machine. But, as the observations were taken twice in twenty-four hours, and as winds sufficient to move these machines may be supposed to have happened sometimes between the times of observation, though at these times the wind might have been below the mean; to compensate this defect, hurricanes are included in the computation.

From these tables then we have the following proportions of the two degrees of winds and upwards, to those below; and likewise of the mean betwixt those two degrees.

Winds

	Days.
Winds of the second degree and upwards in } each week, — — —	4.283
Calms and winds below the second degree,	2.717
Winds of the third degree and upwards,	0.902
Calms and winds below the third degree,	6.098
Winds of a mean proportion between the two } preceding degrees, — — —	2.592
Calms and winds below the mean degree,	4.408

The proportion of these winds in the year comes out in weeks and fractional parts thus:

	Weeks.
Winds of the second degree and upwards in } the year, — — —	31.903
Calms and winds below the second degree,	20.239
Winds of the third degree and upwards,	6.719
Calms and winds below the third degree,	45.423
Winds of a mean proportion between the two } preceding, — — —	19.307
Calms and winds below the mean, —	32.835

From this computation we have 2.592 days in a week,
or 19,307 weeks in a year, in which wind machines of

the heavier kinds, and of considerable friction, may be supposed to be kept in motion; which, to the times wherein they cannot go, is as 10 to 17.

It may be observed, that the resistance to the machine, or its weight and friction, being diminished, though in a small degree, will add considerably to the frequency and length of times in which it can go; since it often happens that there are winds immediately below the lowest degree in the preceding estimate, sufficient to keep the lighter machines in motion. Hence those who have machines which are not absolutely of the heaviest kind, will be apt to conclude this computation erroneous. Besides, there are few who make allowance for, or attend to, the universal law which obtains in mechanics, that in larger machines, their power doth not increase in a proportion so high as their bulk and the resistance arising from their friction.

Computations of this nature, if carried on for a sufficient length of time, might be of some use in regulating insurances, or in pointing out the risks of nautical adventurers, when made in the same climates with the calculation of winds.

Here I should have concluded; but having, after writing what is above, committed these tables and observations to the examination of a learned member of your Society,

ciety, much conversant in these matters, I had the satisfaction to find that he thought them worthy to be communicated to the Royal Society; but remarked, that the materials, which I had proceeded upon, were not so applicable to the purpose as could have been wished. He thinks, that the degrees of winds, being only distinguished into four in the journals from whence those tables have been compiled, are much too few to take in those of the weaker kind, that will however turn well-constructed wind-mills. Indeed I regretted that the table from which I made my estimate contained so few degrees; but it was for that reason I calculated an intermediate degree between the second and the third of our meteorological register. Now as all the degrees above that intermediate degree are sufficient to move the heaviest machine, and the degrees below it insufficient for that purpose, so far as I have been able to observe, it comes to be the same as if the table, from which I made the estimate, had consisted of eight degrees, supposing a mean proportion to be found between the other degrees: thus, 0, $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. this last number $2\frac{1}{2}$, being the lowest degree which I find sufficient for the heaviest machines, would have been 5, had these fractional parts been integers in the table, so that the highest degree, instead of 4 would have been 8. The mean, therefore,

between 2 and 3 being found, will, if I mistake not, answer the preceding objection.

This worthy member, at the end of his observations, says, a mill so constructed may be expected to go the half of the year; that is, I presume, a wind-mill constructed in the neatest and most ingenious manner. But this, I have reason to believe, is far from being the case with wind-mills in this country, they being for the most part clumsy. I doubt not but wind-mills, the construction of which this ingenious gentleman hath directed, though of the same size and consisting of the same numbers with those I have seen here, will nevertheless be moved by a lower degree of wind, and consequently will go a greater proportion of time, though they have the same resistance to overcome as others less artificially constructed. Indeed the same wind machine, as is well known, will require a degree of wind considerably higher when its joints are dry or become gummy, than when they are sufficiently greased. In my estimate I have all along had an eye to the wind machines which have the greatest resistance to overcome, and consequently the machines themselves of the largest kind. But when the learned gentleman supposes a machine to go one half of the year, he may perhaps not understand one absolutely of
the

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the largest kind. Now as the powers of similar machines, but of different magnitudes, are as their cubes, but the resistance arising from their weight and friction as the fourth power; it follows, that a small difference in the size of two or more wind machines will require considerable differences in the winds necessary for their movements.

I am, &c.

TABLE I.

Shewing the Proportion of winds of the second degree and upwards, to those of the first and below, for five years.

	Proportion of winds of the 2d degree to those of the first, &c. in 1731 and 1732.		Proportion, &c. in 1732 and 1733.		Proportion, &c. in 1733 and 1734.		Proportion, &c. in 1734 and 1735.		Proportion, &c. in 1735 and 1736.		Sum of each month for five years.	
	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.
June	16	44	46	14	26	34	24	36	41	19	153	147
July	7	55	44	18	39	23	29	33	43	19	162	148
August	8	54	27	35	20	42	28	34	47	15	130	180
September	30	30	24	36	40	20	34	26	34	26	162	138
October	26	36	13	49	36	26	31	31	35	27	141	169
November	39	21	18	42	51	9	16	44	33	25	157	141
December	43	19	29	33	38	24	46	16	41	21	197	113
January	55	7	43	19	35	27	58	4	45	17	236	74
February	45	13	46	10	48	8	47	9	42	16	228	56
March	39	23	50	12	40	22	53	9	46	16	228	82
April	44	16	34	26	42	18	46	14	46	14	212	88
May	54	8	28	34	36	26	55	7	57	5	230	80
Sum of years and months,	406	326	402	328	451	279	467	263	510	220	2236	1416

TABLE

T A B L E II.

Shewing the proportion of winds of the third degree and upwards, to those of the second and below, for five years.

	Proportion, of winds of the 3d degree to those of the first, &c. in 1731 and 1732.		Proportion, &c. in 1732 and 1733.		Proportion, &c. in 1733 and 1734.		Proportion, &c. in 1734 and 1735.		Proportion, &c. in 1735 and 1736.		Sum of each month for five years.	
	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.
June	1	59	—	60	3	57	2	58	1	59	7	233
July	1	61	7	55	11	51	5	57	1	61	25	285
August	—	62	—	62	8	54	3	59	—	62	48	252
September	13	47	9	51	10	50	8	52	8	52	11	299
October	9	53	1	61	12	50	11	51	2	60	35	275
November	11	49	8	52	19	41	2	58	6	54	46	254
December	17	45	4	58	12	50	9	53	4	58	46	264
January	5	57	11	51	9	53	18	44	6	56	49	261
February	24	34	20	36	24	32	12	44	7	51	87	197
March	12	50	10	52	18	44	6	56	5	57	51	259
April	9	51	5	55	9	51	8	52	5	55	36	264
May	7	55	—	62	9	53	10	52	4	58	30	280
Sum of years and months,	109	623	75	655	144	586	94	636	49	683	471	3183